Spatial and Temporal Measurements of Benthic Optical Properties

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LONG-TERM GOAL

The overall goal of this project is to characterize the spatial and temporal variability of spectral bottom reflectance and the boundary layer of water just above the bottom in optically shallow coastal environments of various bottom types. By measuring ambient, spectral light-field quantities as they change temporally, along with water-column IOP's and other environmental parameters, I hope to achieve a deeper understanding of radiative transfer in optically shallow waters that can be applied to problems in underwater visibility, bottom-type classification, optical bathymetry, hyperspectral remote sensing, and benthic productivity.

OBJECTIVES

In this program I am investigating the temporal changes in bottom spectral reflectance for a variety of bottom types including corals, seagrasses, and both silicate and calcite dominated sediments. Spectral bottom reflectance is expected to change due to changing environmental conditions and forcing mechanisms such as wind and waves, tides, subsurface currents, and solar insolation. Conducting this investigation requires new instruments and methods. Thus one of my objectives is to develop a new type of moored system for measuring the relevant parameters needed to characterize and quantify bottom spectral reflectance and surface remote-sensing reflectance. Related to this objective is to develop shallow-water optical models that can be tested with my HydroRad moorings and with additional shipboard and diver synoptic measurements. A further objective is to measure and model photon propagation in the top layer of sediment and in seagrass canopies to advance our understanding of the parameters controlling reflectance signatures.

APPROACH

Our approach to characterizing and quantifying the spectral bottom reflectance, remote-sensing reflectance, and their changes in time and space, is with a new type of moored system. The major component of this system is a new hyperspectral, fiber-optic multichannel radiometer called HydroRad. HydroRad consists of up to four miniature spectrometers mounted in a watertight pressure housing. Specially designed fiber-optic light collectors, which we developed on this project, are used to collect ambient light with appropriate angular responses for measuring plane irradiance scalar irradiance, and radiance. The spectrometers are OEM model S2000 made by Ocean Optics Inc., and are configured to measure the light spectrum from approximately 400 to 900 nm, with 0.4 nm spectral resolution. The HydroRad instrument contains an embedded controller that digitizes (12 bits) the spectrometer output voltage and stores the data on internal non-volatile memory (48 MB) which can be downloaded onto a

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computer at any time. The controller produces programmed clock signal to the spectrometers that controls the readout rate and integration time. Integration times are automatically chosen by the controller based on the optimal signal-to-noise across the spectrum. Dark current correction is computed in real-time by the embedded controller using dark (masked) pixel measurements and a sophisticated algorithm with parameters derived from temperature calibrations performed in the lab. Thus, dark integrations by shuttering out the light are not required. Power is supplied by internal rechargeable batteries or can be supplied externally. HydroRad data collection can be completely automated for mooring operations, or operated manually as a self-contained instrument.

Six HydroRad-4's (four spectrometers in each unit) were deployed at LSI during the May '99 field campaign. All six were configured to be moored at six different sites. At each HydroRad site, two plane-irradiance collectors were mounted on the bottom, one facing up and one facing down, approximately 10 cm from the bottom. Thus downwelling irradiance and upwelling (reflected) irradiance were measured at the bottom across the spectrum. The ratio of these two measurements gives the bottom spectral albedo, or irradiance reflectance. Two other fiber-optic light collectors are mounted on a surface spar buoy. One of these collectors measures downwelling irradiance just above the surface, and the other collector measures upwelling radiance just below the surface. From these two measurements the remote-sensing reflectance can be derived. The HydroRads were all programmed to make measurements throughout the day at one hour intervals. Figure 1 shows a photograph of a HydroRad mooring system over a seagrass bed at the Channel Marker site at LSI. This particular mooring included HOBI Labs *a*-βeta and *c*-βeta instruments for measuring IOP's, and a FSI current meter.

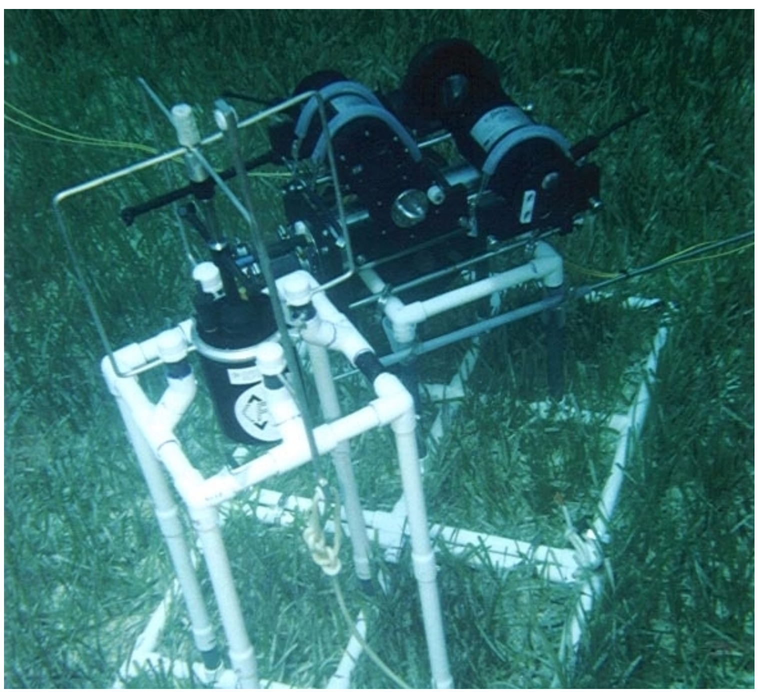

Figure 1. One of six HydroRad moorings deployed around Lee Stocking Island during the CoBOP field campaign in May, 1999. The instrument in the foreground is a two-axis current meter. The two instruments mounted on top of the HydroRad are HOBI Labs a-βeta and c-βeta instruments for measuring IOP's.

WORK COMPLETED

During this reporting period, we developed, built, tested, calibrated, and deployed six HydroRad systems during the CoBOP May '99 field campaign at Lee Stocking Island. During this campaign, we collected continuous, daily measurements of bottom spectral reflectance and surface remote-sensing reflectance and six sites simultaneously. Some of our mooring sites also included HOBI Labs instruments for measuring IOP's near the bottom and one site (seagrass) included a two-axis current meter. In addition to installing and maintaining six mooring sites, we conducted daily surveys of water-column IOP's with HOBI Labs HydroScat-6, *a*-βeta, and *c*-βeta. After the May '99 field campaign we recalibrated all of our instruments and reduced more than 4 GB of data. Most of the data have been analyzed and are currently being used to develop and test shallow-water optical models. In addition to the field campaign at LSI, we have conducted several excursions in Monterey Bay to investigate shallow-water reflectance in different seagrass and sand environments. In collaboration with R. Zimmerman, we developed a diver-operated version of the HydroRad.

RESULTS

The data from the six HydroRad moorings deployed during the May '99 LSI campaign are yielding important insights on benthic optical properties of this region and their relationship to hyperspectral remote-sensing imagery. I have been able to investigate optical closure in shallow-water because of the completeness of the measurements obtained with HydroRad and IOP measurements with *a*-βeta and *c*-βeta [Maffione, submitted]. Figure 2 shows an example of the measurements obtained with HydroRad. This figure shows a simultaneous measurement of surface downwelling irradiance and upwelling radiance, and bottom downwelling and upwelling irradiances from 400 to 900 nm taken over a seagrass bed in the Rainbow Gardens area around LSI.

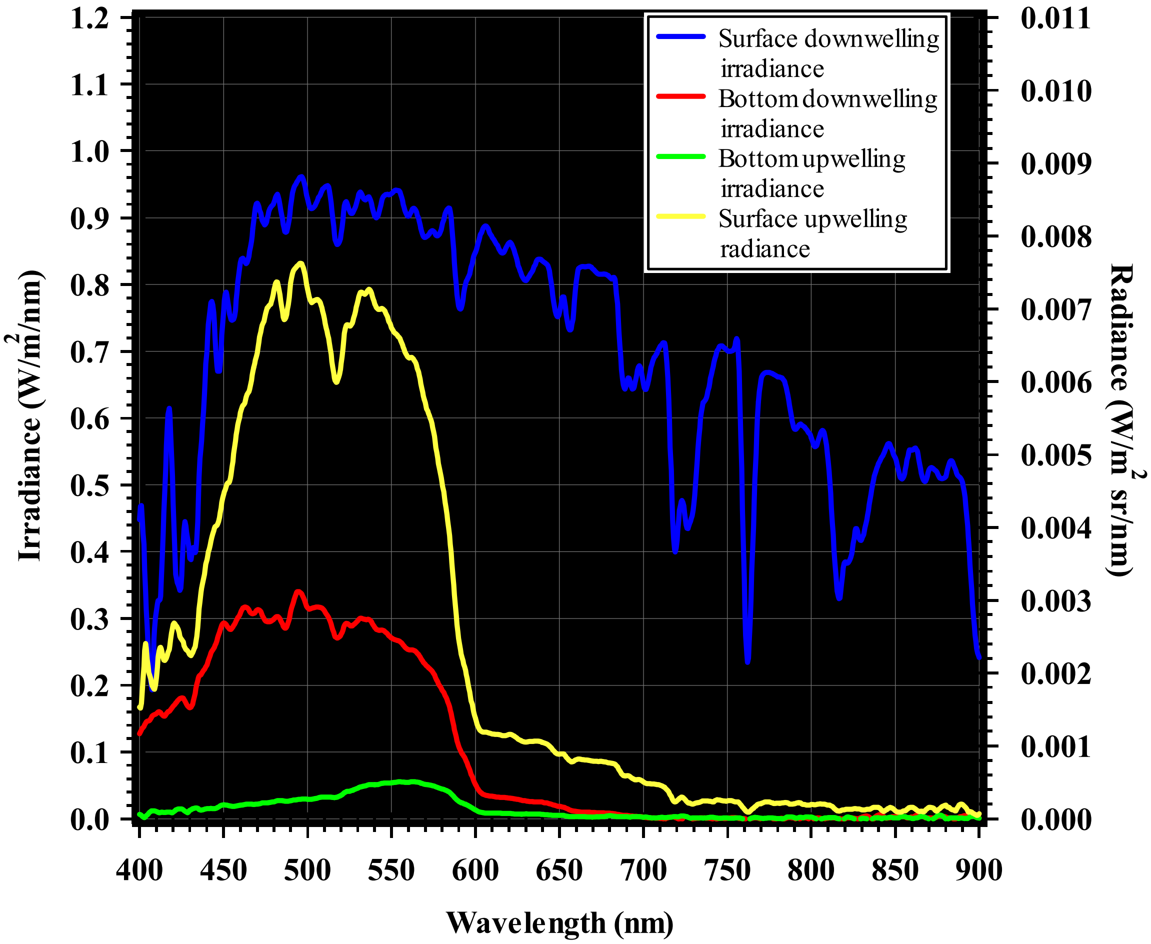

Figure 2. Simultaneous measurements of surface downwelling irradiance, upwelling radiance, and bottom downwelling and upwelling irradiances measured with a moored HydroRad-4 system. Site was a seagrass bed near Rainbow Gardens.

IMPACT/APPLICATIONS

The HydroRad hyperspectral radiometers developed by HOBI Labs as part of this CoBOP program offer a significant advance in instrumentation for measuring spectral light-field parameters, including bottom irradiance reflectance, water column apparent optical properties, and remote-sensing reflectance. The versatility of these new hyperspectral radiometers will have wide application in environmental optics. They can be operated by divers to measure the irradiance reflectance of specific benthic species. They can be easily moored to measure time series of bottom reflectance. And they can be integrated into profiling or buoy systems to measure remote-sensing reflectance and underwater light field parameters. My modeling work on shallow-water remote-sensing is expected to improve optical bathymetry and bottom classification from remote hyperspectral imagery.

TRANSITIONS

The HydroRad hyperspectral radiometers are already being used by investigators on CoBOP and on other ONR environmental optics programs. HydroRads have been transitioned to the HyCODE

program where they are being used on moorings and ships at both the LEO 15 and west Florida shelf sites. HydroRads is also being used on a NOPP project conducted in the Monterey Bay area. The bio-sediment-optical model and seagrass canopy model we developed are being applied to understanding the impact of dredging on seagrass beds in Laguna Madre, Texas. This work is being conducted by a group at Texas A&M and was funded by the US Army Corps of Engineers.

RELATED PROJECTS

I am working closely with J. Paduan, S. Ramp, and L. Rosenfeld of NPS and F. Chavez of MBARI on a NOPP project which involves the HydroRad on moorings in and around Monterey Bay.

I am collaborating with L. Cifuentes and P. Eldredge on studying the effects of dredging and resuspended sediments on seagrass beds in Laguna Madre.

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